U.S. CHEMICAL STOCKPILE DISPOSAL PROGRAM STRUCTURE QUALIFICATION TESTING OF EXPLOSIVE CONTAINMENT ROOMS

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Abstract: This paper discusses the purposes and procedures of Explosive Containment Room (ECR) structure qualification (i.e. pressurization) testing for Chemical Stockpile Disposal Program (CSDP) Demilitarization CONUS sites. Six of the sites contain explosively configured munitions, and therefore have ECR structures. (The six sites are Tooele, Utah; Anniston, Alabama; Umatilla, Oregon; Pine Bluff, Arkansas; Pueblo, Colorado; and Richmond, Kentucky. The Tooele facility is the only CONUS facility already constructed.) The main purpose of the ECR acceptance pressurization testing is to certify compliance with specified leak rates through the structure, i.e. to determine the vapor tightness of the concrete structure, gates, and blast doors. A secondary purpose is to establish a baseline of the structure. In the event of a detonation, another pressurization test could be performed to determine if structural damage had resulted, causing higher leakage rates than the baseline rates. Per the ECR acceptance pressurization test requirements, the maximum acceptable room leakage rate, after pressurizing to 11 pounds per square inch, is 100 standard cubic feet per minute.

The paper briefly discusses the design of each ECR. ECR structures are reinforced concrete designed in accordance with TM 5-1300. Within the ECR, the explosive components of chemical munitions are removed by automatic equipment, requiring containment of blast shock pressures and fragmentation and a high degree of containment of quasi-static gas pressure.

The paper also addresses lessons learned from pressurization testing at the Tooele, Utah facility. Design revisions to electrical conduit penetrations through ECR walls, based on lessons learned, are briefly discussed.

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1.0 INTRODUCTION

1.1 PROGRAM BACKGROUND

As mandated by Public Law 99-145, the U.S. Army Chemical Stockpile Disposal Program (CSDP) mission is to destroy the U.S. inventory of obsolete and unserviceable chemical weapons, with destruction scheduled to be complete by 2004. The U.S. Army Engineering and Support Center, Huntsville (CEHNC) is the Life Cycle Project Manager for design, facility construction, and equipment acquisition and installation for CSDP. The Program Manager for Chemical Demilitarization (PMCD), Aberdeen Proving Ground, Maryland, is assigned overall program management of the CSDP. Destruction of munitions will involve construction of incineration facilities at eight sites within the Continental United States (CONUS). Six of these sites contain mixed munitions that are explosively configured, and therefore these facilities have Explosive Containment Room (ECR) structures. The six sites are Tooele Utah; Anniston, Alabama; Umatilla, Oregon; Pine Bluff, Arkansas; Pueblo, Colorado; and Richmond, Kentucky. The remaining two sites at Newport, Indiana and Aberdeen, Maryland store only bulk containers and therefore do not require ECR structures.

The facility at Tooele, Utah (TOCDF) is the first CSDP facility to be constructed within the CONUS. This facility will utilize the technology from the Johnston Atoll Chemical Agent Disposal System (JACADS). The Johnston Atoll (JACADS) and Tooele, Utah (TOCDF) facilities are already constructed, with JACADS in the operations phase and TOCDF scheduled to begin operations in 1996.

ECRs at the mixed munitions facilities at Anniston, Umatilla, Richmond, Pueblo and Pine Bluff are cloned from the TOCDF ECRs. Furthermore, the TOCDF design serves as a standard for the main process buildings at Anniston, Umatilla, Richmond, and Pueblo. The Pine Bluff facility is located near an existing non-lethal BZ plant and has unique design for the main process building.

1.2 BACKGROUND AND RATIONALE OF PRESSURIZATION TEST

Due to the hazardous operations associated with removing explosive components from chemical munitions within CSDP Explosive Containment Rooms (ECRs), the ECRs must contain blast shock pressures and must minimize the leakage of toxic gases that are released during an explosion. The purpose of the CSDP Explosive Containment Room (ECR) structure qualification (i.e. pressurization) testing is twofold: One purpose is to certify compliance with specified leak rates through the structure, i.e. to determine the vapor tightness of the structure. The second purpose is to establish a baseline of the structure. In the event of a detonation, another pressurization test could be performed to determine if the vapor tightness of the ECR has been compromised, causing higher leakage rates than the baseline rates.

The initial method used in testing the ECR structure is a pressure change measurement method, based on the recommendations and procedures in Reference 1. Similar tests are performed on nuclear reactor structures and these methods were considered in the development of the ECR test procedures.

Per the ECR acceptance pressurization test requirements, the maximum acceptable room leakage rate, after pressurizing to 11 pounds per square inch (psi), is 100 standard cubic feet per minute (scfm). The value of 100 scfm was chosen as a reasonably attainable total leakage rate for the ECR structure. The initial room test pressure of 11 psi was selected as a representative quasi-static pressure caused by an accidental explosion. The selected value of 11 psi for the initial pressure is not high enough to cause significant cracking.

As explained in Paragraph 3.0 below, if the leak rate exceeds 100 scfm, other testing (such as bubble testing or gas sniffer testing) is required to locate the leaks. Leaks are repaired, and the pressurization test is repeated.

2.0 EXPLOSIVE CONTAINMENT ROOM DESCRIPTION

2.1 FUNCTIONAL REQUIREMENTS

The demilitarization process is conducted in a single building, the Munitions Demilitarization Building (MDB). Those munitions with explosive components (i.e. rockets, land mines and projectiles) are placed in two functionally identical Explosive Containment Rooms (ECRs) on the second floor of the building. The explosive components are removed by automatic equipment and then gravity fed to an incinerator (i.e. the Deactivation Furnace System (DFS)) on the first floor. Within the ECR, rockets and land mines are punched and agent is drained into a toxic cubicle on the first floor and incinerated in the liquid incinerator. (However, projectiles are punched and drained in the munitions processing bay, outside of the ECR.) Munitions can be processed in one ECR while maintenance is underway in the other.

Because of the hazardous operations performed on explosively configured munitions in these areas, all personnel in the MDB must be afforded Category I protection from blast and fragment effects for the maximum credible event (MCE). Therefore, the two ECRs are required to contain blast shock pressures and fragmentation and are required to provide a high degree of vapor containment.

The ECRs are reinforced concrete structures designed to provide containment of blast and fragment effects per TM 5-1300 (Reference 2) procedures. Figure 1 shows a plan view of the ECRs and Figure 2 shows a section through the ECR. In each ECR, there are two process input conveyors and a single output conveyor, two personnel entry doors, several utility penetrations and a floor penetration for gravity feed of munition components into the DFS. Each ECR has a continuous ventilation system with supply and exhaust duct penetrations. Blast and fragment resistant closures are provided in each duct at the containment wall penetration. All doors,

conveyor gates and drop chutes in the ECRs provide blast and fragment resistance. Door assemblies are installed in the ECR prior to placing concrete to assure a reliable installation and a tight fit. All conveyor gates and doors have compression seals to limit leakage after a blast to specified maximum values.

Interior surfaces of the ECR are coated with an agent resistant paint. This finish prevents agent from permeating the concrete and provides a smooth resistant finish for regular washdown with decontamination solutions. The coating also significantly improves the gas tightness of the structure.

2.2 DESIGN CONSIDERATIONS

The ECRs are designed for structure reusability in the event of an explosive incident by using structural damage criteria that is much more restrictive than values normally used in hardened structure design. The ECR concrete structural elements are designed to limit maximum joint rotations to one degree under dynamic loading, which is more restrictive than the 2 degree rotation criteria in TM 5-1300. The one degree rotation criteria is intended to limit cracking which could influence the leak tightness of the structure. For quasi-static pressures, the ECR concrete elements are designed to remain elastic. In order to prevent perforation or spalling of exterior surfaces from worst-case fragments, large concrete thicknesses were used. Steel elements, such as blast door, conveyor gates, and utility penetrations are designed to remain elastic.

Pressure decay in a containment structure, such as the ECR, is a function of two characteristics--structure leakage and the rate at which the confined hot gas products cool after an incident. Leakage from the ECR is due to the combinations of leakage through blast valves during closure; leakage around doors, conveyor gates, utility penetrations; leakage through the DFS feed chute, and leakage through microcracks in the concrete. The rate of this leakage is a direct function of the internal pressure after an event, and is directly proportional to the differential pressure between the ECRs and the surrounding areas after an incident. As the confined gas cools, pressure decays fairly rapidly, and the leakage rate decreases proportionately.

Although the ECRs are unlined concrete structures, small leakages of hazardous gases through the ECR are contained by the building ventilation system. (A liner plate was not used in the design of the ECRs, due to the significant cost of the liner plate, and the risk of agent contamination behind the liner.) The ventilation system is designed to provide increasing levels of negative pressure from non-hazardous areas towards hazardous areas. This prevents leakage of toxic vapors from hazardous areas to other areas.

Various ventilation categories are used to identify the potential for agent presence. The ECR is ventilation category A, which is the most toxic, and is the most negative in the cascade ventilation system. Ventilation category A/B is less toxic and negative than category A, and ventilation category C is less toxic and negative than A/B. The areas surrounding the ECR are

category A/B. Workers in A and A/B areas during operations will wear respiratory protection; workers in C areas will not wear respiratory protection. For these reasons some vapor leakage can be allowed from the ECR to the surrounding A/B area, but no vapor leakage can allowed to the C areas.

In the event of an explosive incident, the ventilation ducts are quickly isolated to prevent damage and personnel risk to the remainder of the building. This protection is achieved by using a fast-acting blast valve, followed by a gas-tight (isolation) valve.

3.0 ECR ACCEPTANCE PRESSURIZATION TESTING

3.1 GENERAL

Upon completion of construction of the ECR structure, the gas tightness of each ECR is quantified by performing a pneumatic leak test. The ECR rooms are pressure tested to certify compliance with specified leak rates through components identified as blast doors and conveyor blast gates. The pressure decay method is used for the initial testing. If specified leak rates are exceeded, then bubble solution tests, air-ammonia tests, gas sniffer tests, or ultrasonic leak detector tests are performed to determine leak sources.

3.2 EQUIPMENT REQUIRED

The following equipment and instrumentation are required to perform the tests:

a. Compressed air supply 600 scfm minimum at 15 psig minimum pressure.

b. Room pressure gage, 0 - 15 psig range.

c. Room temperature indicating device, accurate and readable to plus or minus 0.5 seconds.

d. Timer, readable to at least plus or minus 0.5 seconds.

e. Barometer, accurate and readable to at least 0.10 inch Hg.

f. Room air supply manifold 2-inch diameter pipe with shut-off and bleed valves.

g. Covers to seal drain, ventilation, and other openings not to be included in the room leak test.

h. Bubble solution, a commercial test solution, a solution of equal parts liquid detergent, glycerine and water, anhydrous ammonia, a tracer gas that can be detected with a sniffer, or an ultrasonic leak detector.

3.3 PRETEST PROCEDURES

Before formal pressurization testing, the contractor will provide and install pipe plugs, caps, and cover plates with gaskets to seal off openings not included in the leak test such as open end pipes and electrical conduits installed through the penetration plates but not yet connected to their respective final networks. DFS feed chute floor opening and HVAC supply and exhaust air openings will be covered with temporary gasketed plates.

A visual inspection is performed to determine that components are installed in conformance with the applicable drawings and specifications. The contractor is to repair all damaged or distorted blast gate and door frames, penetration plates, and fissures or cracks through the concrete walls, that are detected during the visual inspection or while performing the pressurization testing.

3.4 TEST PROCEDURES

Total room leakage is determined from the change of pressure in the room from beginning to end of the test, as explained in ASME N510 (Reference 3). To calculate the total leakage rate, the room volume is measured and the room pressure and temperature is recorded at the start, during, and at completion of the pressure test. The following specific procedures are followed:

a. Connect compressed air source to room supply pipe. Verify that both the shut-off and bleed valves are closed.

b. Record room volume and the perimeters of each blast door and gate to be leak tested.

c. Verify doors and gates are closed.

d. Open compressed air supply shut-off valve. Observe room pressure temperature and test area barometric gage readings.

e. Close shut-off valve when 11.0 psig room pressure is achieved. Start timer, recording pressure and temperature of enclosed air.

f. Record pressure readings at one minute intervals until pressure decays to 9.0 psi, or for a maximum of 15 minutes, and record temperature after final pressure readings taken.

g. Calculate leak rate from the following equation:

$$Q = (P_i/T_i - P_f/T_f)\ [V/(R_A\ (t_f - t_i)\ (0.075))]$$

Where:

Q = average volumetric leakage rate, standard cubic feet per minute (scfm)
V = volume of room, ft^3
P_i = initial pressure in room, lb/ft^2 ABS
P_f = final pressure in room, lb/ft^2 ABS
T_i = absolute temperature at start of test, degrees Rankine
T_f = absolute temperature at end of test, degrees Rankine
t_f = time at start of test, minutes
t_i = time at end of test, minutes
R_A = gas constant for air, 53.35 ft-lb/lb degrees Rankine
(0.075) = density of STD air lb/ft^3

h. If leak rate is at or below the specified acceptance value of 100 scfm, the test is completed and acceptable.

i. If leak rate exceeds 100 scfm, locate leaks by the bubble test method as follows:

1.   Open compressed air supply shut-off valve, observe room pressure gage, close valve when 11.0 psig pressure is obtained.
2. Apply soap solution to joints to be tested. A few minutes later, but before the soap solution can dry, check the wetted area and mark places where bubbles are being generated.
3. A leak indication shall be any bubble 1/16 in. diameter that forms in one second, or a bubble 9/32 in. that forms in one minute.

l. As alternate test methods to the bubble test, air-ammonia test, the gas sniffer test, or the ultrasonic leak detector test methods may be used. These tests are explained in ASME N 509 (Reference 4) and ASME N510 (Reference 3) leakage rate testing of containment structures for nuclear reactors. The exception is that halogen compounds, such as Freon and Halon, shall not be used.

m. After the room with components are tested, depressurize the room by slowly opening bleed valve. Examine leak areas and correct or repair leak sources and retest room following the previously specified test procedure.

n. After retest, depressurize room by slowly opening bleed valve.

o. If room leakage rate still exceeds specified acceptance value, perform individual component leak test on blast doors and gates. Install seal cover plates over room blast gates and retest room following the previously specified test procedures. Calculate specific leak rates from the following equations.

$q_{door} = Q_2 / C_{door}$

$q_{gate} = (Q_1 - Q_2) / C_{gate}$

where:

q_{door} = blast door specific leak rate, scfm/ft
q_{gate} = blast gate specific leak rate, scfm/ft
Q_1 = room leak rate from total room leakage test in paragraph 3.4m, scfm
Q_2 = room leak rate from component leak test in paragraph 3.4o, scfm
C_{door} = length of perimeter of blast doors, ft
C_{gate} = length of perimeter of blast gates, ft

If the component specific leak rates exceed 0.05 scfm/ft, deficiencies shall be corrected by an approved procedure, and the room with component shall be retested until acceptable results are attained.

p. After completion of testing, depressurize the room the slowly opening bleed valve. Disconnect compressed air pipe connection. Remove all seals used for the test from room openings.

4.0 LESSONS LEARNED

As noted earlier, the JACADS and TOCDF facilities have already been constructed. As required by the project specifications, ECR pressurization tests were conducted at both sites. The tests confirmed that the vapor tightness of the ECR concrete structure, gates and blast doors were within acceptable limits.

However, during the ECR pressurization testing at TOCDF, leakage was determined to have occurred through several electrical conduits. Based on lessons learned from the TOCDF ECR pressurization testing, improvements have been made to the design drawings and specifications for electrical conduits passing through the ECRs.

The original design included a conduit seal fitting on the less toxic side near the penetration plate whenever a conduit runs from a higher toxic area to a lower toxic area. When wiring installation is complete the fitting is filled with a sealing compound. Based on lessons learned from previous testing, improvements to the electrical conduit design include the following:

a. Figure 3 shows revised design details of seal fittings for conduits running from the ECR into surrounding areas, i.e. the ECR Vestibule (ECV) and the Unpack Area (UPA). The ventilation categories (A, A/B, and C) shown on the figure are based upon the potential for agent presence.

As discussed in Paragraph 2.2, some vapor leakage can be allowed from the ECR to the surrounding A/B areas, but no vapor leakage can be allowed to the C areas.

b. Figure 3 shows the modification to include two seal fittings on the less toxic side of the ECR, immediately following the penetration from the ECR. The first (primary) seal fitting outside the ECR will always be filled with a compound after wiring installation. The second seal fitting will not be filled unless installation testing indicates failure of the primary seal.

c. The conduit will be subjected to an in-situ smoke test to verify the integrity of the first (primary seal).

d. If the installation fails the smoke test, then the second seal fitting will be filled with a seal compound and the installation retested.

e. A fire retardant fitting (Figure 3) is added beyond the backup seal fitting. After successful conduit installation testing, the fire retardant fittings will be filled with a fire retardant polyurethane seal compound.

f. As shown in Figure 3, if the conduit passes straight from the ECR through other adjacent areas and then to a lower toxic area (e.g. Unpack Area UPA, Category C), then design details will include another primary seal fitting and a fitting for the fire retardant seal at the lower toxic area. These seals are in addition to the seals shown in Figure 3 immediately outside the ECR.

g. The electrical specifications are modified to enhance conduit installation training, installation instructions, and quality assurance.

The above improvements have been incorporated into drawings and specifications for CSDP mixed munitions sites following TOCDF. Similar improvements have been incorporated at TOCDF and JACADS.

5.0 CONCLUSIONS

Due to the hazardous operations associated with removing explosive components from chemical munitions within CSDP Explosive Containment Rooms (ECRs), containment of blast shock pressures and fragmentation and near total containment of quasi-static gas pressure must be provided. Upon completion of construction of the ECRs, the gas tightness of each ECR is quantified by performing a pneumatic leak test. This test also establishes a baseline of the structure. In the event of a detonation, another pressurization test could be performed to determine if the vapor tightness of the ECR has been compromised, causing higher leakage rates than the baseline rates.

Pressurization tests have already been conducted at the JACADS and TOCDF facilities. These tests confirmed that the vapor tightness of the ECR concrete structure, gates and blast

doors were within acceptable limits. Based on lessons learned from the TOCDF ECR pressurization testing, improvements have been made to the CSDP design drawings and specifications for electrical conduits passing through the ECRs.

6.0 REFERENCES

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2. "Structures to Resist the Effects of Accidental Explosions", US Army Technical Manual TM 5-1300, Washington, DC, November 1990.

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4. ASME N509 Nuclear Power Plant Air-Cleaning Units and Components, 1993.

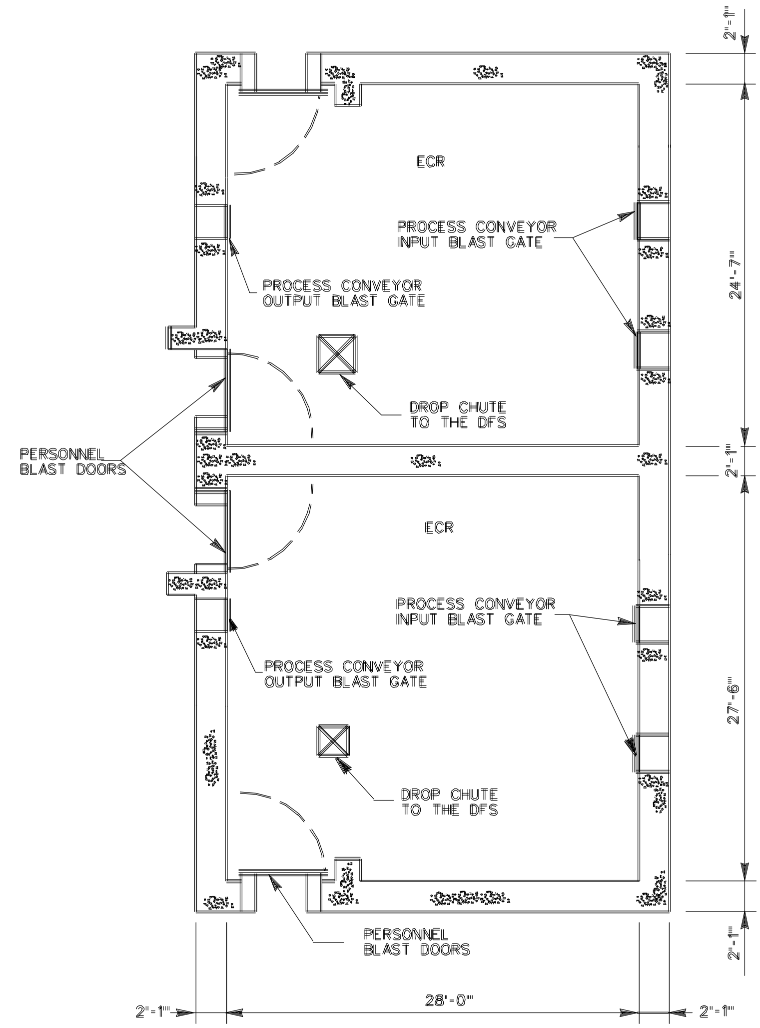


Figure 1 - Explosive Containment Room Plan

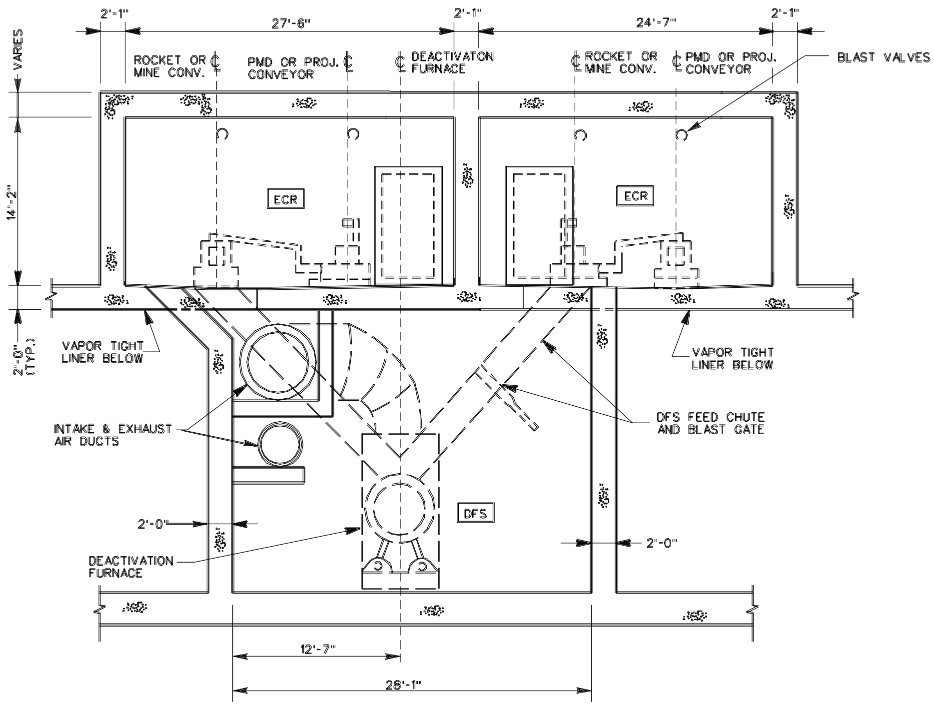
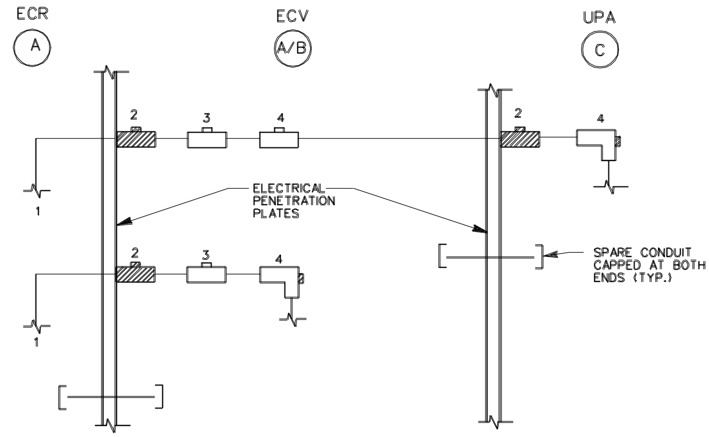


Figure 2 - ECR/DFS Section



ITEM	DESCRIPTION
1	ELECTRICAL CONDUIT
2	PRIMARY SEAL
3	SECONDARY SEAL
4	FIRE RETARDANT FITTING

Figure 3 - Electrical Conduit Seals